Vehicle to Everything (V2V, V2I, V2X, C2C, C2X)
R&S test solutions for Automotive

**GNSS / eCall**
- R&S®CMW
- R&S®SMBV

**Automotive Radar Solutions**
- R&S®SMW
- R&S®SMF
- R&S®ARTS
- R&S®ZVA110
- R&S®FSW
- R&S®SMZ

**Car2Car / Car2X**
- R&S®CMW
- R&S®FSW
- R&S®FSWP

**Audio / Video / Infotainment**
- R&S®CMW
- R&S®BTC
- R&S®VTC
- R&S®UPP
- R&S®RTO

**GNSS Simulation Solutions**
- R&S®TS9982
- R&S®SMB100A
- R&S®FSW
- R&S®NRP
- R&S®RTO

**Complete EMC measurement solutions.**

**Automotive Bus Systems**
- R&S®CMW
- R&S®RTM
- R&S®RTO
- R&S®RTH

**Evaluation of Driver Assistance Systems**

**Communication and Interference**

**Bus analysis with dedicated options for CAN, BroadR-Reach...**

**Verifying the quality of infotainment systems**

**Company Restricted**
Research & Development

- Transmitter tests
- Receiver test

Design & Validation

- RF Parametrics
- Co-existence
- Functionality
- Performance
- Power analysis

Pre-Compliance & Compliance

- Standard compliance
- Regulator compliance

Manufacturing

- Calibration
- Verification
- Go / NoGo
A car2car module of the following components:
- 802.11p chip, 2 tx/rx antennas (to avoid package losses), GNSS receiver and CAN / USB interface.

General T&M Requirements:
- Repeatability (not only drive tests)
- Generation and Analysis of 2 x 5.9 GHz 11p test signals
- PER testing
- Multipath simulation
What do we need to test in R&D?

Goal: Verify basic receiver and transmitter performance in a realistic but repeatable environment including fading.

- **Transmitter**
  - Channel Power ACLR
  - Spectrum Emission Mask
  - Occupied Bandwidth
  - CCDF

- **Receiver**
  - Minimum input sensitivity (sensitivity of the DUT at very low input levels)
  - Maximum Input Level (demodulate an 11p signal with a high input level)
  - Adjacent and Nonadjacent channel rejection (demodulate a signal in the presence of an interfering signal)
Manufacturing

Research & Development
- Transmitter tests
- Receiver test

Design & Validation
- RF Parametrics
- Co-existence
- Functionality
- Performance
- Power analysis

Pre-Compliance & Compliance
- Standard compliance
- Regulator compliance

Manufacturing
- Calibration
- Verification
- Go / NoGo
What do we need to test in Design and Validation?

Goal: Ensure that a product or system fulfills the defined user needs and specified requirements, under specified operating conditions.

- RF Parametrics
- Co-existence
- Functionality
- Performance
- Power analysis
What do we need to test in Design and Validation?

**Rx Quality Analysis**

R&S®WinIQSIM2
Configuration of 802.11 waveforms

- Power Measurements:
  - Burst Power
  - Power vs. Time
- Modulation Accuracy:
  - EVM
  - Frequency Error
  - Symbol Clock error
  - Chip Clock Error
  - I/Q quality
- Spectrum Analysis:
  - Spectral Flatness
  - Transmit spectrum mask
  - Occupied bandwidth

**Tx Measurements**

Standard RF measurements:

- 802.11 a/b/g (option KM650)
- 802.11n (option KM851)
- 802.11p (option KM655)
- 802.11 ac (option KM656)
Research & Development
- Transmitter tests
- Receiver test

Design & Validation
- RF Parametrics
- Co-existence
- Functionality
- Performance
- Power analysis

Pre-Compliance & Compliance
- Standard compliance
- Regulator compliance

Calibration
Verification
Go / NoGo

Manufacturing
Pre-compliance and Compliance Testing?

Goal: Verify the device passes the necessary conformance requirements

- Standard compliance
- Regulator compliance
TS-ITS100 - System software (Europe)

Regulatory tests according to R&TTE* ETSI EN 302 571

<table>
<thead>
<tr>
<th>ITSG5A Test Cases</th>
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<td>5.3.3.2</td>
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<td>5.3.7.9.2</td>
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<td>5.3.8.3.2</td>
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Testing to protect other regular radio services

TS-ITS100 - System software (Europe)
Car-2-Car Communication Consortium (C2C-CC)

Performance tests

To ensure proper services additionally performance tests are required

ETS and C2CCC (ETSI TC ITS WG4) are discussing currently the specification of such performance tests inclusive a certification program

Tests under discussion for

Receiver minimum performance requirements

- Receiver sensitivity (under fading conditions)
- Decentralised congestion control (DCC) minimum performance requirements
  - Channel load threshold verification
  - Channel load measurement accuracy
  - Channel load quality under time-varying, multipath propagation conditions

TS-ITS100 - System software (Japan)

Regulatory tests according to ARIB STD-T109

2.1 The test item for the technical requirements for the physical layer

- 2.1.1 Modulation accuracy
- 2.1.2 Reception sensitivity (Packet error rate)
- 2.1.3 Maximum input power for reception
- 2.1.4 Blocking characteristics

TS-ITS100 - System software (USA)

Test cases according to IEEE 802.11-2012

- 18.3.9.2 Transmit power levels
- 18.3.9.3 Spectrum Mask
- 18.3.9.4 Transmission spurious
- 18.3.9.5 Center frequency tolerance
- 18.3.9.6 Symbol clock frequency tolerance
- 18.3.9.7.2 Transmitter center frequency leakage
- 18.3.9.7.3 Transmitter spectral flatness
- 18.3.9.7.4 Transmitter constellation error
- 18.3.10.2 Receiver minimum input sensitivity
- 18.3.10.3 Adjacent channel rejection
- 18.3.10.4 Nonadjacent channel rejection
- 18.3.10.5 Receiver maximum input level
- 18.3.10.6 CCA requirements (depends on the availability of CCA values in the DUT API)
- 18.3.10.7 Received Channel Power Indicator Measurement

TS-ITS100 - System software (Japan)

Regulatory tests according to TELEC T257

1 The test item for the technical requirements for the physical layer

- 1.1.1 Frequency tolerance
- 1.1.2 Occupied bandwidth
- 1.1.3 Antenna power tolerance
- 1.1.4 Intensity of spurious or unwanted emissions
- 1.1.5 Transmission data rate
- 1.2.1 Limits of incidentally produced radiation
- 1.3.1 Interference prevention function
- 1.3.2 Carrier sense function
- 1.3.3 Transmission time control function
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<th>Research &amp; Development</th>
<th>Design &amp; Validation</th>
<th>Pre-Compliance &amp; Compliance</th>
<th>Manufacturing</th>
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<tr>
<td>Transmitter tests</td>
<td>RF Parametrics</td>
<td>Standard compliance</td>
<td>Calibration</td>
</tr>
<tr>
<td>Receiver test</td>
<td>Co-existence</td>
<td>Regulator compliance</td>
<td>Verification</td>
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<td></td>
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<td></td>
<td>Performance</td>
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<td></td>
<td>Power analysis</td>
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</tbody>
</table>

**Manufacturing**
- Calibration
- Verification
- Go / NoGo
What do we need to test in Production?

Goal: Automated verification of device function, at the end of the manufacturing process.

- Reference Calibration Tests
  - RSSI parameter
  - TX Output power
  - Flexible settings of frequencies

- Reference Verification Tests
  - RSSI
  - CINR
  - Constellation Error (EVM)
  - TX Output Power Go / NoGo

- Go/No Go
What do we need to test in Production?

The Communication Tester combines signal analysis and signal generation in a single instrument. For time optimized RF calibration in non-signalling mode, the tester provides fast transmitter measurements and a versatile arbitrary waveform generator for receiver testing.
What do we need to test in Production?

An alternative setup is based on Spectrum Analyzer and a Signal Generator remote-controlled via IEEE 488.2 (GPIB) or LAN.
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- R&S®NRP
- R&S®BBA

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- R&S®RTO
- R&S®RTH

**Communication and Interference**

GNSS Simulation Solutions

Complete EMC measurement solutions.

Evaluate the quality of infotainment systems

Bus analysis with dedicated options for CAN, BroadR-Reach...
The Technology behind V2X
ITS Stages and Key Communication Technologies

Stage 1
Roadside Comm
Wired or wireless communication for infrastructure

Stage 2
Telematics
Infotainment, on-line navigation, remote diagnostics, e-call communications

Stage 3
ITS - BSA
V2V/V2I (V2X) communication to warn drivers potential risks and improve traffic efficiency. (Basic Set of Apps).

Stage 4
New technology?

90s’
2000s’
2010s’
2020s’
2030s’

HUWEI TECHNOLOGIES CO., LTD.

Accident-free, driver-less traffic, autonomous driving. Achieve vehicle / road /environment harmony. (Enhanced Set of Apps)
Vehicle-to-Vehicle (V2V) Communication Today

Ad-hoc network (IEEE 802.11p)

Cellular network (GSM, UMTS, LTE)
ITS and 802.11p

**Intelligent Transportation System (ITS)**

summarizes applications for traffic management as Car-to-X or navigation. Target is to make
- road user better informed
- traffic safer
- traffic more coordinated

**Car-to-X (Vehicle-to-X), communication based on 802.11p**

- between vehicles (Car-to-Car / Vehicle-to-Vehicle)
- with roadside units
- with motorcycles
- with bicycles
- with pedestrians (e.g. apps on mobile phones)
IEEE 802.11p – technical facts

- amendment to IEEE 802.11a standard (published 2010)
- mobile ad-hoc network (WLAN) w/o central infrastructure
- no signalling or authentication
- only broadcast mode on a 10 MHz channel

- supports data exchange between high-speed vehicles and between vehicles and roadside infrastructure (required by ITS)
- fulfills requirements for safety applications because of low latency
R&S Signal Generators for 802.11p

802.11p Fading Profiles:

- 802.11p operates in fast moving environments
- Receiver tests under fading conditions are important

- ETSI is adding test cases for fading to the standard
- Same fading profiles as used in ETSI plugfest in Nov. 2013, where R&S took part
- R&S SMW-200A will support these special fading profiles.
V2V Communication System Comparison

Cellular network
- Reliable coverage / no range limitation
- Collision handling
- Operator dependence
- Shared resources / system overload

Ad-hoc network
- Limited range
- No handover
- >10-15% market penetration is required
- Independent solution / reserved resources

Operator dependence
Network-Controlled Ad-Hoc Network

- Unifies the advantages of both concepts
- Allows to select appropriate air interface for application
Rel-13 Sidelink enhancements

- **Priorities**: Prio1, Prio2, Prio3
- **Groups**: Group1, Group2
- **UEs**: UE1, UE2, UE3, UE4, UE5
- **eNBs**: eNB1, eNB2
- **Out of coverage for discovery**
- **Inter-carryer / Inter-PLMN**: Rel-12 Rx only, Rel-13 Rx and Tx
- **UE relay for communication**: UE1
- **Multiple transmissions within one SC period**: T1, T2, SC period n, SC period n+1
- **Coordination**
LTE-D2D has paved the way for V2X communication.

3GPP SA1 has started Rel-14 LTE-V2X SI from 2015 Feb with most companies’ support.

3GPP RAN has started LTE-V2X SI from June 2015, V2V part to complete in 2015, the rest in 2016 (Rel-14)

In China, a series of LTE-V2X SI/WI have been setup at CCSA and C-ITS.

LTE-V2X is the first step for V2X in 3GPP. When it comes to 5G, even lower latency and higher reliability will be supported.
TS-ITS100 - System software (Europe)

Regulatory tests according to R&TTE* ETSI EN 302 571

<table>
<thead>
<tr>
<th>ESO (1)</th>
<th>Reference and title of the harmonised standard (and reference document)</th>
<th>Reference of superseded standard</th>
<th>Date of cessation of presumption of conformity of superseded standard Note 1</th>
<th>Article of Directive 1999/5/EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETSI</td>
<td>EN 302 571 V1.1.1 Intelligent Transport Systems (ITS): Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&amp;TTE Directive</td>
<td></td>
<td></td>
<td>Article 3(2)</td>
</tr>
</tbody>
</table>

*European Radio equipment and Telecommunications Terminal Equipment (R&TTE) Directive
Regulatory tests according to R&TTE ETSI EN 302 571

ITS-G5A Test Cases

- 5.3.2.3.2 Carrier Frequencies
- 5.3.3.3.2.1 RF output power at the highest level
- 5.3.3.3.2.2 Power Spectral Density
- 5.3.4.3.2 Unwanted emissions outside 5 GHz ITS band
- 5.3.5.3.2 Unwanted emissions inside the 5GHz ITS bands
- 5.3.6.3.2 Spurious Emissions
- 5.3.7.3.2 Selectivity
  (contains Adjacent, Non-adjacent and Blocking test case)
- 5.3.8.3.2 Sensitivity

Testing to protect other regular radio services
TS-ITS100 - System software (Europe)
Car-2-Car Communication Consortium (C2C-CC)

Performance tests

- To ensure proper services additionally performance tests are required
- ETSI and C2CCC (ETSI TC ITS WG4) are discussing currently the specification of such performance tests inclusive a certification program

Tests under discussion for

- Receiver minimum performance requirements
  - Receiver sensitivity (under fading conditions)
- Decentralised congestion control (DCC) minimum performance requirements
  - Channel load threshold verification
  - Channel load measurement accuracy
  - Channel load quality under time-varying, multipath propagation conditions
C2C scenario specific channel models
for receiver performance tests under real world conditions (fading)

<table>
<thead>
<tr>
<th>Rural LOS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intended primarily as a reference result, this channel applies in very open environments where other vehicles, buildings and large fences are absent.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urban Approaching LOS:</th>
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</thead>
<tbody>
<tr>
<td>Two vehicles approaching each other in an Urban setting with buildings nearby.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Street Crossing NLOS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two vehicles approaching an Urban blind intersection with other traffic present. Buildings/fences present on all corners.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highway LOS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two cars following each other on Multilane inter-region roadways such as Autobahns. Signs, overpasses, hill-sides and other traffic present.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highway NLOS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>As for Highway LOS but with occluding trucks present between the vehicles.</td>
</tr>
</tbody>
</table>

Source: Cohda Wireless
Regulatory tests according to ARIB STD-T109

2.1 The test item for the technical requirements for the physical layer

- 2.1.1 Modulation accuracy
- 2.1.2 Reception sensitivity (Packet error rate)
- 2.1.3 Maximum input power for reception
- 2.1.4 Blocking characteristics
Regulatory tests according to TELEC T257

1 The test item for the technical requirements for the physical layer

- 1.1.1 Frequency tolerance
- 1.1.2 Occupied bandwidth
- 1.1.3 Antenna power tolerance
- 1.1.4 Intensity of spurious or unwanted emissions
- 1.1.5 Transmission data rate
- 1.2.1 Limits of incidentally produced radiation
- 1.3.1 Interference prevention function
- 1.3.2 Carrier sense function
- 1.3.3 Transmission time control function
TS-ITS100 - System software (USA)

Certification Operating Council (COC) based on IEEE 802.11-2012

- COC TP-80211-TXT-PHY-BV-01: Spectrum mask
- COC TP-80211-TXT-PHY-BV-02: Center frequency tolerance
- COC TP-80211-TXT-PHY-BV-03: Symbol clock frequency tolerance
- COC TP-80211-TXT-PHY-BV-04: Constellation RMS error
- COC TP-80211-TXT-PHY-BV-05: Spectral flatness
- COC TP-80211-TXT-PHY-BV-06: Center frequency leakage
- COC TP-80211-TXT-PHY-BV-07: Transmit power function
- COC TP-80211-RXT-PHY-BV-01: Minimum input sensitivity
- COC TP-80211-RXT-PHY-BV-02: Adjacent channel rejection
- COC TP-80211-RXT-PHY-BV-03: Nonadjacent channel rejection
- COC TP-80211-RXT-PHY-BV-04: Maximum input level
- COC TP-80211-RXT-PHY-BV-05: Received channel power indicator measurement
- IEEE 18.3.9.4: Transmission spurious

Available on TS-ITS100